Energy Consumption Feedback: Engagement by Design

Ruth Rettie, Kevin Burchell, and Tim Harries

Kingston University, Kingston Hill, Surrey, KT2 7LB, UK
{r.rettie,k.burchell,t.harries}@kingston.ac.uk

Abstract. This paper reports two energy feedback studies and explores the role of design in increasing householder engagement with energy feedback. The paper discusses a range of design issues that arise when developing an energy feedback system. It argues 1) that it is important to provide feedback in terms of activities rather than energy units, which have little relevance to householders, and 2) that emphasising the avoidance of waste could help to make energy consumption visible and prompt changes in energy consuming behaviours.

Keywords: energy consumption feedback, social norms approach, feedback design, randomised control trial, community research.

1 Introduction

The provision of energy consumption feedback to householders has emerged as an important climate change mitigation strategy in a number of countries. In the UK, for instance, a nationwide roll-out of electricity and gas smart meters, and in-home displays (IHDs) is planned for some 30 million homes between 2015 and 2020. IHDs are included in the UK smart meter project on the grounds that the information they provide will 'help [householders] manage their energy use, save money and reduce emissions' [1, p1].

2 Theoretical Background

Electricity differs from most other consumer products in being abstract, invisible and intangible and in only being consumed as a by-product of other practices [2]. Its consumption has been compared to a situation where products don't have price labels and bills are only sent out at quarterly intervals [3]. Research shows that consumption feedback reduces domestic energy consumption by between 2% and 15% [4-8]. Recent ethnographic studies suggest that consumption feedback can increase the visibility and salience of energy consumption and of related behaviours, and can prompt re-evaluation, behaviour change and consumption reduction [9-16]. However, these studies also identify a number of factors that constrain the effectiveness of energy feedback: householder engagement with feedback tends to be relatively short-lived and may be limited to one person within the household; people find it hard to relate their feedback to their everyday activities around the home and when feedback prompts a desire to change this may be confounded by household conflict.

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Energy feedback can include normative comparisons with the energy use of others in what is known as the social norms approach (SNA) [17-18]. The SNA attempts to influence behaviour by changing perceptions of what is normal. The approach assumes that descriptions of what is normal behaviour can simplify decision-making by acting as a heuristic short-cut or 'nudge' [19]. The social norms approach has been applied to electricity consumption feedback by providing feedback about average consumption alongside individual household feedback [6, 20]. These two US studies examined the impact of a programme implemented by Opower that mailed reports containing social norms with households' bimonthly/quarterly electricity bills. With samples of 85,000 [20] and 600,000 [6] and intervention periods of one year and two years, respectively, these evaluations found reductions of 2% - 2.35%. However, these studies did not distinguish the impact of social norms feedback from that of feedback of a household's own consumption, because social norms feedback was always presented to participants alongside their own household's data (see Fig. 1).

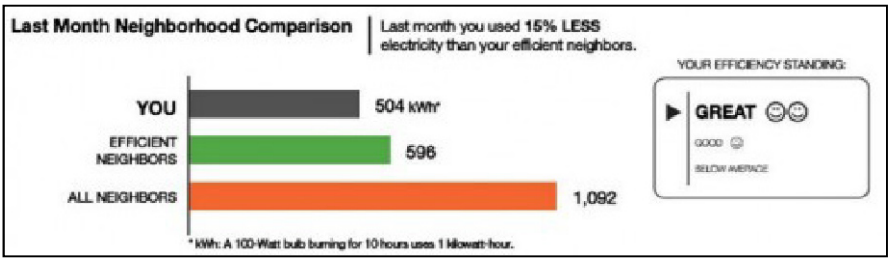

Fig. 1. Opower feedback evaluated by Allcott [6]

3 Methodology

The paper is based on two studies in which energy consumption and normative feedback about other households played a key role: the CHARM Home Energy Study, an 18-week randomised controlled trial involving 316 households (www.projectcharm.info) and Smart Communities, a 2 year community action project involving 400 participants (www.smartcommunities.org.uk).

3.1 The CHARM Home Energy Study

The CHARM Home Energy Study compared the effect of individual household feedback with that of social norms feedback. The randomised controlled trial therefore compared three experimental conditions: 1) feedback that included only data about an individual household's consumption; 2) feedback that also included a neighbourhood average, and 3) a control condition without feedback.

Fieldwork took place in Bristol, UK. Over 400 households were professionally recruited, door-to-door, from one poorer and one richer area of the city, using an £80 incentive. Three hundred and sixteen households (79% of those recruited) successfully completed the 18-week study and the pre- and post-study questionnaires. Technological collaborators at the University of the West of England built electricity

consumption monitoring devices that automatically sent data to the study server via the mobile telephone network.

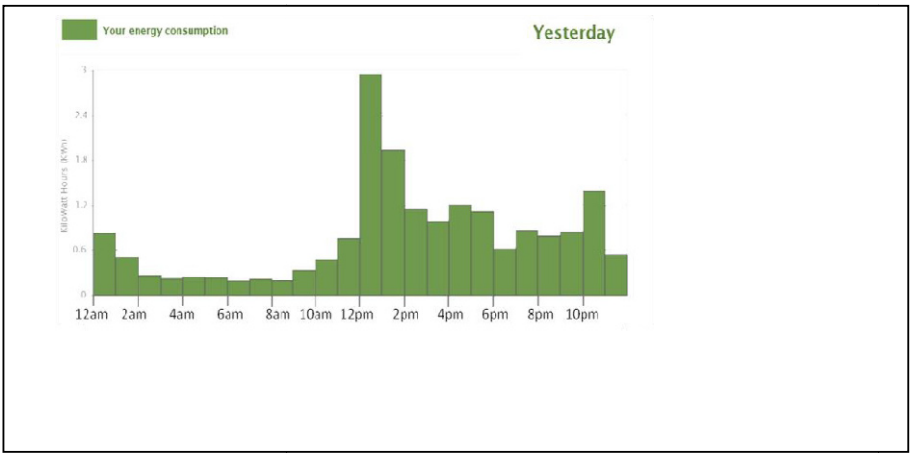

Fig. 2. An example of a graph for participants in the individual feedback condition

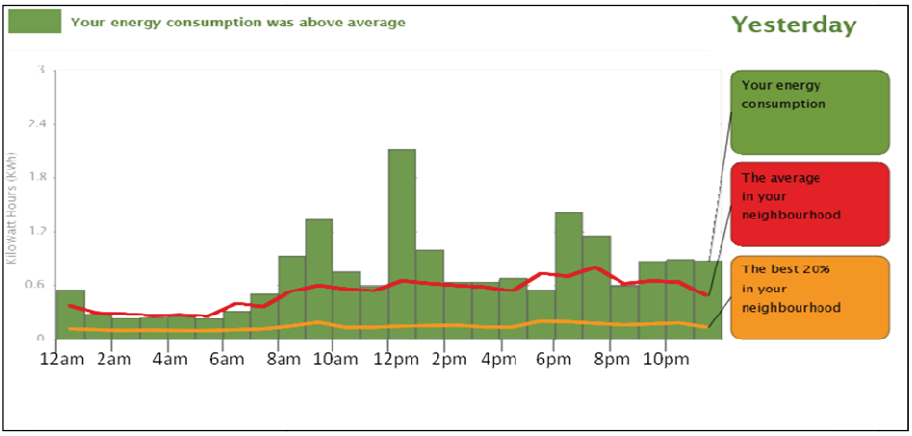

Fig. 3. An example of a graph for participants in the social norms feedback condition

After a two-week baseline period feedback was provided to those in the two intervention conditions using graphs showing usage for the current day, the previous day, the previous seven days and from the start of the study (for examples, see Fig. 2 and 3). For those in the social norms condition, this feedback included information on average consumption for other households in their locality (the higher of the two lines, in red) and the consumption of the lowest consuming 20% (the lower line, in orange). They also included statements that reflected the household's position relative to the average, with smiley emoticons if consumption was below average (see Table 1). Participants were able to access all four types of graph on personalized, password-protected websites and were each sent a weekly marketing email containing one recent graph and one

energy-saving tip. The websites and emails also contained generic tips on household energy saving. Fortnightly mobile phone SMS reminded participants to read their emails and access their web pages - e.g. 'How has your electricity usage changed over the past two months? Login at homeenergystudy.org to find out'.

Table 1. Social norms messages used in graphs for the social norms condition

Condition	Descriptive norms	Injunctive norms
Consumption above average for those in the social norms condition	Your energy consumption was above average	None
Consumption 0-30% lower than average	Your energy consumption was just below average	☺ Well done, keep it up!
Consumption 31-59% lower than average	Your energy consumption was well below average	☺☺ Well done, keep it up!
Consumption lower than average by 60%+	Your energy consumption was among the best 20%	☺☺☺ Well done, keep it up!

The CHARM project monitored how much electricity participants used and recorded how often they looked at the feedback. In addition, analysis included pre- and post-trial questionnaires, 21 in-depth interviews and three focus groups.

The study was conducted at a time when increasingly long days and warmer weather were causing a reduction in electricity consumption for all the participants. However, linear regression analysis showed that average consumption levels reduced by 3% more for those who received feedback than for those who did not [12]. The sample was not large enough to test the statistical significance of this unexpectedly small effect, but comments by participants in the interviews suggest that the feedback did lead to changes in energy-consuming behaviours. For example, some participants reduced their use of tumble driers; some purchased low-energy white goods, and some reduced their use of standby. The interviews suggest that the main reason the feedback had this effect was that the graphs provided householders with benchmarks against which to compare their usage – i.e. their own consumption at different times of day or the consumption of other people. This made it easier for users to see when their usage was higher than usual, to relate this usage to particular practices, to see this usage as potentially wasteful, and to make changes to their behaviour. For further details of the findings from this study please see [12].

3.2 Smart Communities

Smart Communities was a two-year community project in Kingston-upon-Thames involving families of children attending a local primary school, together with other households in the area [21]. The project combined community action activities (such as workshops, bespoke guidance and demonstrations in people's homes and activities in the school) with electricity and gas consumption feedback, and weekly emails. Feedback followed the social norms approach, as shown in Fig. 4. Leaflets were

distributed door-to-door to homes within the geographical area of the project, while parents at the school were invited to join through leaflets in school book bags.

Over 400 out of approximately 2000 eligible households (about 20%) joined Smart Communities by logging onto the project website. Smart Communities participants were sent a basic electricity in-home display (IHD) showing both real time and cumulative electricity consumption (see Fig. 5). They were sent weekly email reminders to read their cumulative energy consumption data from their household monitors and enter this data into a My Energy section on the project website. Participants' websites then showed their weekly consumption alongside the average energy consumption and the best 20% consumption for the community as a whole (see Fig. 4). They were also able to view their feedback relative to the number of people living in their house and the number of rooms in their homes.

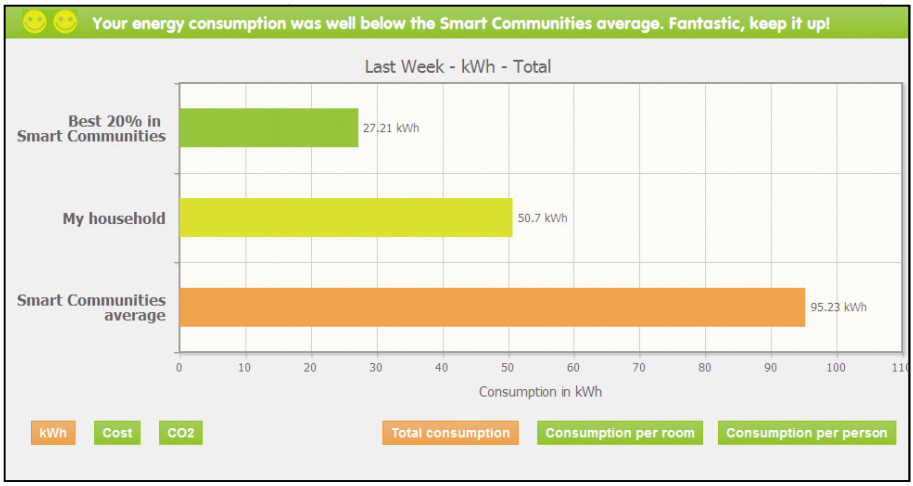

Fig. 4. An example of feedback on the Smart Communities website

Fig. 5. The IHD used in the Smart Communities project

Project fieldwork included 50 in-depth interviews (37 with project participants, 5 with non-participating residents of the area, and 8 with project partners), five workshops, a focus group with school children and an end of study survey questionnaire (n=460). Analysis of the project data demonstrates long term engagement with feedback. After two years, about 50 participants were still entering their weekly energy consumption readings into the Smart Communities website, and 40% of survey respondents who had IHD's claimed they looked at them daily. Participants who had IHDs learned a lot about their energy consumption, and made some changes around their homes (for example, with respect to lighting, use of the kettle, showering and use of heating). However, participants found it easier to change some behaviours than others (e.g. switching off lights in unoccupied rooms) and many treated their everyday ways of doing things as fixed ('the washing is the washing!', as one project participant put it).

4 Design Issues in the Two Projects

There are many issues and alternatives to consider when designing an energy feedback system. The impact of the feedback is likely to depend on the manner in which it is communicated – e.g. the choice of medium, the choice of unit and the layout of any web-pages. Some of the issues and alternative identified in our work are shown in Table 2.

Table 2. Energy consumption feedback design alternatives

Design Element	Examples of options
Communication medium	website, email, post, SMS, mobile or tablet app
Design	
positioning	environmental, energy management, budgetary control
benefit	save money, save energy, avoid waste
style	modern, geeky, sophisticated, traditional
Information	
fuel	gas, water, oil
disaggregation	disaggregated by fuel type, appliance, room, practice, user
units	money, kWh, kg of carbon dioxide
period	hourly, daily, weekly, monthly, bill period
graphs	bar, line, pie
advice	personalisation, descriptive or injunctive
Social norms comparisons	
reference group	house size, occupancy, housing type
basis of comparison	Total, disaggregated by practice or appliance

4.1 Communication Medium

The CHARM study provided feedback via password protected websites and in weekly emails. In contrast, Smart Communities provided web-based feedback but used weekly emails to encourage participants to enter their energy readings on their

websites. The research indicates that in both studies the weekly emails were accessed regularly and often appreciated. However, some users found it difficult to access password-protected websites, either because of low levels of web-literacy or because they forgot their passwords.

4.2 Design

Both projects avoided an overtly environmental positioning (though both used the colour green in the project logos and leaflets). The CHARM Home Energy Study was positioned as research on energy consumption and Smart Communities was positioned as a community project that would save participants energy and money. The surveys conducted in the two studies indicate that only a small percentage of our participants were environmentally conscious. The interviews in both studies suggest that users were generally more motivated by avoiding wasting energy than by either the money saved or the effect on the environment.

As shown in Fig. 2, 3 and 5, the design of feedback in both the CHARM and Smart Communities projects was simple and direct, using large blocks of easily distinguishable colours, sans serif fonts and bar charts.

4.3 Feedback

The CHARM study provided near real-time feedback charts (with about ½ hour lag) that showed hourly consumption (see Fig. 6). Participants were also able to access charts that showed daily usage for the previous week or since the start of the study. Usage data suggests that the charts showing hourly consumption were accessed most frequently. These made it easy for participants to identify and attribute consumption to particular appliances or practices – for example, in Fig. 6 the peak between 12 and 1pm suggests lunch-related energy consuming activities such as cooking. The interviews suggest that the charts had the effect of highlighting 'waste' because anything dramatically higher than usual was treated as a possible waste of energy.

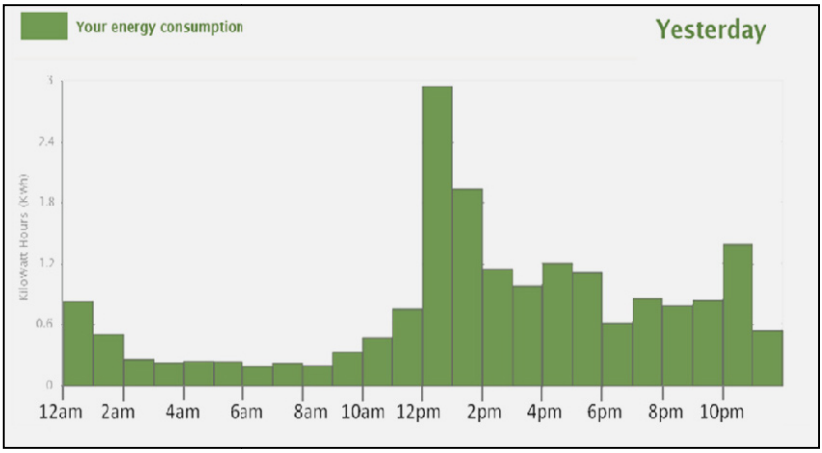

Fig. 6. Hourly feedback in the CHARM Home Energy Study

The time period used is important because if it is too long it is difficult to relate usage to behaviour. The CHARM Home Energy Study showed cumulative consumption for periods of an hour or a day. Our research suggests that hourly or half-hourly feedback makes it easier for participant to relate their usage to their behaviour.

Smart Communities participants received feedback both on personalised websites and on in-home displays (IHDs) that displayed current and cumulative usage (in a choice of kWh, £ or kg of CO2). They were encouraged to enter the cumulative figures from the IHD into their personalised websites, which calculated weekly energy consumption for that household and displayed this alongside figures for the average and the 'best 20%' Smart Communities households for the same period. The Smart Communities interviews suggest that current usage figures, such as those shown on IHDs, can mislead users into thinking that an appliance that has high energy consumption for a short period of time, such as a kettle, uses a lot of energy overall.

Both projects used bar charts to represent energy consumption. The CHARM study also used lines to represent the average consumption of other users and the average consumption of 'the best 20% in your neighbourhood' (see Fig. 3). The interviews suggest that users found the charts easy to understand, even though energy consumption was shown in kWh, which they did not really understand. They have no sense of what a kWh is or of whether 1000 kWh is a lot or a little. The unit of kWh can also be confusing, because it can be interpreted as measuring the rate of energy used per hour (in the same way that mph is miles per hour) but is actually a measure of energy consumption (kW is a measure of the rate of use of energy - 1kW is 1000 joules of energy per second). However, the CHARM research suggests that the use of kWh did not matter, because participants focused on their relative use of energy rather than on the amount of energy used, for example comparing their usage at different times. The graphs in both projects were self-scaling. This meant that the size of the bars shown on the graphs changed when the scales changed, for instance, to accommodate a particularly high usage. Unfortunately, this meant that participants who focused on relative usage or on patterns of usage could misread their usage if they did not notice changes in the scale of the graphs.

Both the CHARM and Smart Communities projects provided overall rather than disaggregated consumption; the interviews suggest that users would welcome disaggregation in terms of appliances or practices.

The CHARM and Smart Communities projects both included energy reduction tips on their websites, but these were not personalised to the user or their energy consumption. Tips were also provided in weekly emails and in the case of CHARM, in SMS; these tips were seasonally appropriate, for instance advising on insulation in winter or advocating line drying in summer, but again were not personalised to the user. Advice that is tailored to the circumstances of a particular household (as in the personal energy advice provided by British Gas and other utilities in the UK) is likely to be more salient and therefore more motivating. Energy advice systems can also automatically provide advice linked to feedback and the user's profile, rather than expecting the user to search for advice (i.e. 'push' rather than 'pull' communication). Energy saving advice can either be descriptive, for example, describing the amount of energy that could be saved with insulation, or injunctive, exhorting householders to

improve their insulation. Strengers [13] suggests that injunctions are more likely to challenge established practices.

4.4 Social Norms Feedback

The CHARM Home Energy Study and Smart Communities both used social norms feedback. In each case the studies followed the format used in the OPOWER research (see Fig. 1) by including both the average of all users, the average of the 'best 20%' and up to three 'smiley' emoticons (see Table 1) for those who were below average. The interviews indicate that the social norms feedback was well received and stimulated interest and a degree of competition between households. The CHARM analysis did not find any difference between the energy consumption of those households in the individual condition and those in the social norms condition. However, those receiving individual feedback opened an average of 14 emailed graphs (standard deviation 13.81) while those receiving the social norms feedback opened 20 (standard deviation 21.18); this difference is statistically significant, and suggests that users find feedback more engaging if it includes social norms data.

Use of the social norms approach in other domains shows that the impact of the approach on any individual is increased if comparisons are made with the most appropriate reference groups [22, 23]. In the CHARM study we were unable to target specific reference groups, and so the social norms feedback was the average total consumption of all households receiving social norms feedback. It is possible that feedback targeted at relevant reference groups (for instance, people living in similar houses or people with large families) might be more effective. Similarly, social norms feedback disaggregated for specific practices or appliances might be more effective than feedback of overall consumption.

4.5 Designing Consumption Feedback

The alternatives discussed above reflect some of the design issues that arise when developing an energy feedback system. Generally the research in the two projects suggests that it is important to provide feedback in terms of everyday activities rather than just in terms of energy units, and that even when social norms feedback is engaging it may not have an impact on consumption.

Although the research in the two projects suggests that the feedback had some impact on consumption, this effect was smaller than anticipated. The next section considers why energy consumption feedback appears to have only a small impact on consumption.

5 Motivating Behaviour Change

There is a tacit assumption among some researchers and suppliers of energy feedback that simply providing energy feedback will lead to significant reduction in energy consumption; this is belied by the research [4-7]. It is easy to assume when designing

energy consumption feedback that householders have both a desire to reduce their energy consumption and a deficit of information, and therefore that providing information in the appropriate design format will lead to changes in behaviour and a reduction in consumption. However, as noted in the theoretical background above, energy consumption is indirect and often invisible, and measured in units that most householders do not understand. Ironically, this renders problematic the provision of energy consumption feedback. Strengers [14] argues that current forms of energy feedback are based on a mistaken assumption that most householders are the rational micro-resource managers imagined in the 'smart ontology' that underlies the design of most consumption feedback. Harries and Brightwell [24] suggest that control and management of electricity can also conflict with the caring ethos of home-making.

Ethnographic research [9-16] shows that feedback can make energy more visible, but also suggests that current forms of feedback do not challenge those energy-consuming practices that are taken-for-granted by householders. Strengers [14] calls for forms of feedback that challenge and disrupt these practices, and emphasises the inclusion of normative messages. One possible way of using established norms to challenge existing practices emerged from the two studies reported here. The research suggests that for some people the avoidance of waste is a moral imperative and more motivating than saving the environment, saving energy or saving money [12, 21, 24]. It is possible that a focus on wasteful usage might increase awareness of energy consumption and motivate behaviour change more effectively than consumption feedback. Such a focus could be achieved via the visualisation of wasteful usage (such as occurs in unoccupied heated bedrooms or poorly insulated homes), perhaps using interactive animated digital displays.

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